



Here is an early 1930s view of the WFLA-WSUN antenna system, showing the station building and the two towers. (From "RCA Broadcast News," July 1932)

The Development of the Directional AM Broadcast Antenna

By John Schneider W9FGH

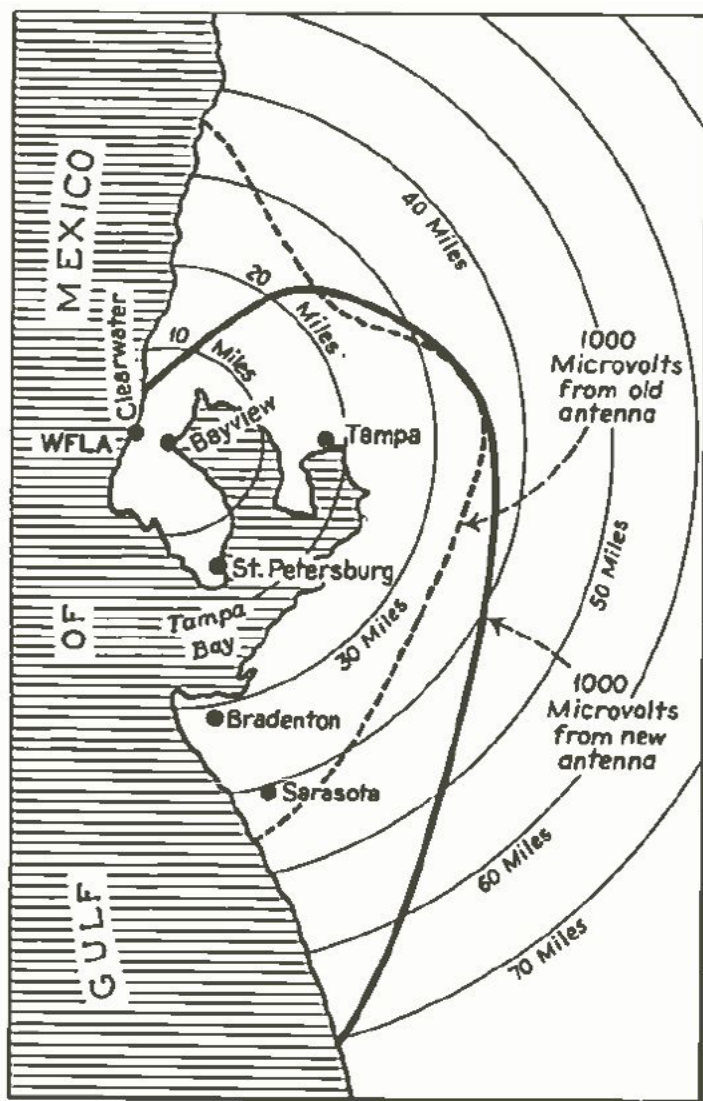
In the early years of AM radio broadcasting, all stations utilized non-directional antennas. Most all of these were wire antennas suspended between towers or buildings. Interference, especially at night was severe. An interfering signal of 5 percent or less in signal strength was enough to disrupt reception of the desired station, and if the frequencies of the two stations were slightly separated, there would be a heterodyne beat note. As a result, only a few widely spaced stations could operate on each of the AM broadcast channels in the entire country at night. This limited the number of stations that could coexist to about 500 nationwide, with many of them sharing time on a single frequency.

As antenna technologies were developed and improved in the early 1930s, a few progressive stations began experimenting with multi-element directional arrays. It offered two attractive benefits: 1) It could reduce radiation towards other stations on the same or adjacent frequencies, permitting

more stations to share a frequency; 2) a broadcaster could direct more signal towards the desired coverage area, and away from wasted areas such as open water in the case of coastal stations.

WSUN-WFLA

The first known use of a directional antenna was by a pair of stations in Tampa/St. Petersburg, Florida. In 1927, the Clearwater Chamber of Commerce acquired station WGHF and changed the call sign to WFLA. A companion station, WSUN, was operated by the St. Petersburg Chamber of Commerce. The two stations shared the frequency of 900 kHz, broadcasting on alternate evenings to promote tourism and business opportunities in their respective communities. In reality, they operated with two station licenses but there was only one transmitter and one antenna.



WFLA-WSUN in Clearwater, Florida, built the country's first AM broadcast directional antenna in 1932. This coverage map shows how the signal was reduced to the north of the transmitter to protect a Milwaukee station, while improving the signal to the east, west and south. (Radio Engineering magazine, June 1934)

In 1929, in a nationwide realignment of radio frequencies, the Federal Radio Commission (FRC was the precursor to today's FCC) moved WFLA-WSUN to 620 kHz with a power of 2 kW daytime and 1 kW nighttime. Immediately, WTMJ in Milwaukee, Wisconsin, which also operated on 620 kHz, filed an objection with the radio commission, stating that its coverage was being impacted by interference from the Florida stations. The commission responded by reducing WFLA-WSUN's power to 500 watts daytime and 250 watts nighttime. This news was distressing to the two chambers of commerce—at those power levels, they would not have the nighttime coverage they needed to promote their communities to the rest of the country.

WFLA-WSUN contacted a Washington consulting engineer in desperation to try and find a solution. He was T. A. M. Craven, a former high-ranking naval communications officer who had resigned his commission in 1930 to go into private practice as a radio consulting engineer. Craven, in

turn, called on Dr. Raymond Wilmotte, a British radio engineer who had previously experimented with radio direction-finding technologies in Europe. Wilmotte immigrated to the USA in 1929 and was working for the Boonton Aircraft Corporation. Craven encouraged Wilmotte to leave his job and open his own consulting practice. Together, Craven and Wilmotte proposed the erection of a directional antenna that would reduce WFLA-WSUN's radiation towards Milwaukee, allowing the stations to operate at a higher power level. At first, the owners were skeptical of investing in an untried technology. Other equally respected engineers believed that a working directional antenna was not possible—they thought the ionosphere would distort the signal's directional properties. But Wilmotte was certain it would do the job, and he proposed that he not be paid unless the project was a success. With such an assurance, WFLA-WSUN gave him the go-ahead.

Wilmotte had two base-isolated vertical towers constructed. Each was 200 feet high, separated by a quarter wavelength on a bearing towards Milwaukee. The towers were on opposite sides of what is now the Courtney-Campbell Causeway in Clearwater. The power from a new 5 kW Western Electric transmitter was divided at the transmitter building and sent to each tower via open-wire transmission lines suspended from poles. The system was configured so that the two towers could be operated in-phase during the day and 90 degrees out of phase at night, creating a cardioid pattern with a sharp null towards Milwaukee.

The first tests were conducted in May 1932. There were lots of trial-and-error adjustments as they became educated in the unexpected complication of mutual impedances (the adjustment of one tower would change the tuning of the other tower). Finally, a precise adjustment was achieved, and the system worked even better than expected - so much so that the government engineer in Atlanta who was assigned to measure the signal strength asked why the station was off the air—he could not hear the signal at all!

This feat of engineering immediately caught the fascination of the country's broadcasters, and it boosted the careers of both engineers. Broadcasting magazine foresaw the significance of directional antenna technology when it wrote:

"The day when broadcasting stations will be enabled to predetermine their coverage and actually steer the course of their signals in given directions is envisioned. ... Interference troubles, through the use of this new directional radiating system, can be sharply curtailed, and at the same time make possible substantial increases in coverage in given directions, by putting the punch in the signals covering desired markets, and by cutting off propagation over useless areas."

WSUN-WFLA was allowed to increase its power and operated successfully from the two-tower system for the next 18 years. (The stations separated in 1941 when WFLA moved to another frequency and both became full-time.)

A few years later, T.A.M. Craven would become the



This view shows the transmitter building and two of the four towers that Westinghouse built in 1934 for KYW at Whitmarsh, twelve miles outside of Philadelphia. (From a 1930s KYW publication)

FCC's Chief Engineer, and then was appointed by Franklin Roosevelt as an FCC commissioner. He held the position from 1937 to 1944 and was the only engineer ever to serve as a commissioner. For his part, Dr. Wilmotte went on to patent an anti-fading two-section vertical AM antenna. He also helped create direction-finding systems for airports, was involved with the development of radar, and then joined RCA to help develop the first communications satellites. In the 1970s, the FCC tapped him to develop a high-performance UHF-TV tuner. He died on January 27, 2000, at the age of 98.

KYW Philadelphia

In 1932, the Federal Radio Commission determined that the clear-channel 1020 kHz frequency should be reassigned from the Midwest to the Mid-Atlantic States, in an effort to equalize the distribution of clear-channel frequencies across the country. That 1020 frequency was occupied by KYW in Chicago, owned by the Westinghouse Corporation. A number of other broadcasters applied to the FRC to take over the channel, but Westinghouse ultimately convinced the commission to allow it to move KYW from Chicago to Philadelphia.

As one of the foremost innovators in the art of radio electronics, Westinghouse had the advantage of employing some of the country's best radio engineers. They set to work designing an innovative directional antenna system for the new 10,000-watt KYW transmitter site that was to be built at Whitmarsh, 12 miles north of Philadelphia. The array consisted of four 200-foot steel poles that formed the four corners of a rectangle, spaced by a half wavelength on the long side of the rectangle and one-third wavelength on the short side. Each pole was mounted in an insulated cradle atop a

45-foot-tall lattice wooden base. The towers were fed by individual transmission lines from a phasing circuit that separately controlled the current and phase of each tower. For the ground system, 55,000 feet of copper wire was formed into counterpoise cages suspended horizontally ten feet off the ground around the base of each mast. The resulting figure eight antenna pattern was designed to maximize signals over Philadelphia and Allentown while creating a null towards New York City to protect WHN. The raised tower bases were chosen to minimize fading at the edges of the KYW ground wave service area.

The KYW transmitter building and its contents were equally innovative. The colonial-style stone building was designed to blend in with the surrounding residential neighborhood. The custom-built Westinghouse transmitter was the first high-power rig to be completely operated from AC power, eliminating the use of troublesome DC motor-generators. It incorporated nitrogen-filled capacitors, which were more compact than the air-dielectric capacitors then in common use. All transmitter components were built on open steel frames which were completely enclosed inside a room-within-a-room. Interlocks on the doors prevented the operators from entering while the transmitter was in operation.

After several weeks of testing from the new site after sign-off in Chicago, Westinghouse made the official switch to Philadelphia on December 3, 1934. In 1940, KYW's transmitter power was increased to 50,000 watts, and the station moved to 1060 kHz in the 1941 NARBA treaty nationwide frequency realignment. The original antenna system was in used until 1949, when it was replaced with the two 450-foot towers that are still in use today.

WLW Cincinnati

Between 1934 and 1939, WLW in Cincinnati, Ohio, was the first (and only) AM radio station in the United States ever authorized to operate with the remarkable transmitter power of 500 kW. Upon being granted this coveted experimental authority by the FCC, the Crosley Radio Corporation spent a half million depression-era dollars to construct the country's most powerful radio facility. Broadcasting on WLW's clear-channel 700 kHz frequency, the super-power transmitter at first only operated after 1:00 AM using the experimental call sign W8XO, but after it proved reliable it was authorized to operate 24 hours a day using the WLW call sign.

The existence of such a powerful signal on the radio airwaves was certain to create interference. And sure enough, in the summer of 1934 the FCC began receiving complaints from the Canadian government about interference to CFRB, which operated with 10 kW on 690 kHz in Toronto, 400 miles northeast of Cincinnati. "With station WLW operating with 500 kilowatts," read the official complaint, "the service area of the Toronto station was reduced to little more than the city of Toronto itself, and 50 miles out the signals from Toronto were completely obliterated."



This aerial view shows the WLW antenna complex in Cincinnati in 1935. The station's main 831-foot diamond-shaped Blaw-Knox tower is at the upper right. The two 326-foot towers in the foreground were the "suppressor antennas" designed to reduce WLW's signal towards Toronto. (Author's collection)

WLW's experimental license needed to be reauthorized by the FCC every three months, and WLW dutifully filed to renew the authorization that would expire in February 1935. But the FCC's response was the cancellation of WLW's temporary authority, stating that it was obligated to comply with the international treaty that governed the sharing of the airwaves. WLW would be allowed to operate with 500 kW during the day but would have to reduce its power to 50 kW at night. Although the FCC had closed the door, it left open a tantalizing window—the commission would approve 500 kW nighttime operation "providing such a radiating system is employed that the effective signal delivered in the area between Niagara Falls, New York, Lockport, New York, and Lake Ontario does not exceed the effective signal in that area when operating with 50 kW."

In the 1930s, the evening hours were radio's "prime time," and WLW stood to lose a lot of advertising revenue if it couldn't operate its super-power rig in the evenings, and so its engineers wasted no time in coming up with a solution to this unforeseen impediment. After analyzing twenty different possible solutions, the Crosley engineers chose to erect two

326 ft. "suppressor" antennas to reduce the signal intensity towards CFRB. These two towers were constructed 1,850 feet away from the main 831-foot WLW tower, located directly in line on the bearing towards Toronto. The height and location of these towers were chosen to reduce the skywave signal towards Toronto at an angle of 20 degrees above the horizon.

By April of 1935, WLW was conducting evening tests at 500 kW. Both the FCC and Canadian engineers took field measurements and were satisfied that the system was effectively reducing the signal towards Toronto to the 50-kW level.

Simultaneous to the Canadian issue, the FCC received another objection of possible WLW interference from WOR in New York. WOR was on 710 kHz and was concerned that the proposed reduction in signal strength towards Toronto would result in an increase in signal towards WOR. In response, WLW quickly sent a team of engineers to the east coast to make field measurements. When they proved to WOR that there would be no objectionable interference, the WOR complaint was withdrawn and WLW resumed its full



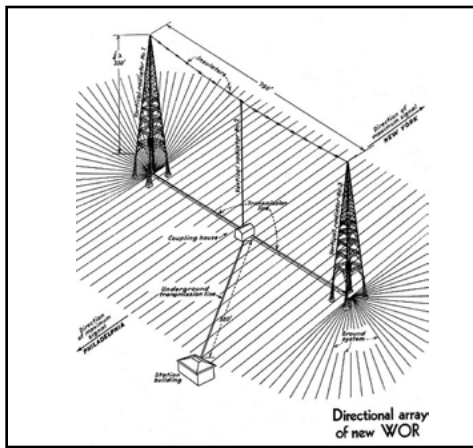
Above: This coverage map shows WLW's original 500 kW non-directional nighttime coverage (dashed lines), and the coverage achieved with the directional antenna (solid lines). The signal towards Toronto was greatly reduced to protect station CFRB. (Author's collection)

power evening broadcasts on May 8. It continued to broadcast at this power level as the industry and government argued over the benefits and evils of super-power broadcasting. Finally, under pressure from Congress, the FCC set a ceiling of 50 kW on all AM broadcasting in the United States. WLW's days as a super-power broadcaster came to an end on March 1, 1939.

WOR Newark, New Jersey

Beginning in 1922, the Bamberger Department Store had been operating station WOR, which was licensed to the store's headquarters in the city of Newark, New Jersey (WOR was relicensed to New York City in 1941). In 1935, the station decided to increase its power from 5 kW to 50 kW and moved its transmitter from Kearny, New Jersey, south to the village of Carteret. A new 35-acre site was built on the shores of the Arthur Kill channel, across from Staten Island, New York.

The WOR engineers, led by broadcast pioneer Jack Poppele, wanted a directional antenna that would maximize the signal towards New York City to the Northeast and Philadelphia to the Southwest, while minimizing radiation over the mountains of Pennsylvania and the Atlantic Ocean. They contracted with the AT&T subsidiary Western Electric to build the new transmitter



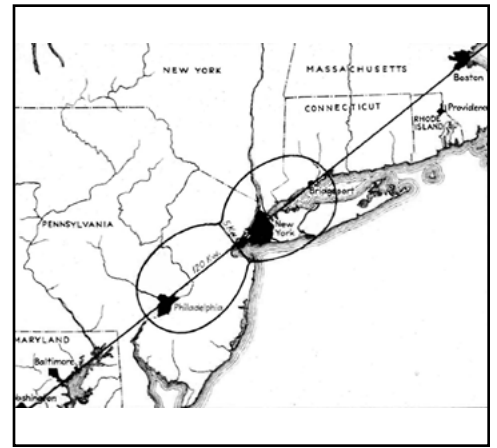
Left: This drawing shows the configuration of the WOR antenna system at Carteret, NJ, constructed in 1935. ("Broadcasting" Magazine, 3/1/1935.) Right: This map shows the theoretical WOR antenna pattern, with an equivalent power of 120 kW in the main lobes and only 5 kW in the nulls. (Electronics magazine, February, 1935)

site, which in turn employed their engineers at the Bell Telephone Laboratories, to design a directional antenna system.

The WOR antenna consisted of two self-supporting 385-foot base-insulated towers, which served as two elements of the directional array. They supported a taut cable that stretched 790 feet between the tops of the towers, and a drop-wire conductor that descended from this cable at the midway point served as the third antenna element. The ground system consisted of 40 miles of number 8 buried copper wire. This was one of the first radio installations to use coaxial transmission line, which was also buried. The three elements of the antenna were fed in phase, which produced a broadside figure-eight array favoring New York City and Philadelphia.

Inside the spacious and windowless operations building, the 50,000 watt WOR transmitter was enclosed behind windows with a corridor running around it which allowed visitors to view the inner workings of the system from all angles. The heat extracted from the water-cooled transmitter tubes was used to heat the building.

On March 4, 1935, President Franklin Delano Roosevelt threw the ceremonial switch to launch the new WOR signal, and a gala day-long program was broadcast from Carnegie Hall to inaugurate the powerful transmitter. The Carteret site remained in operation until 1968, when WOR moved to Lynd-



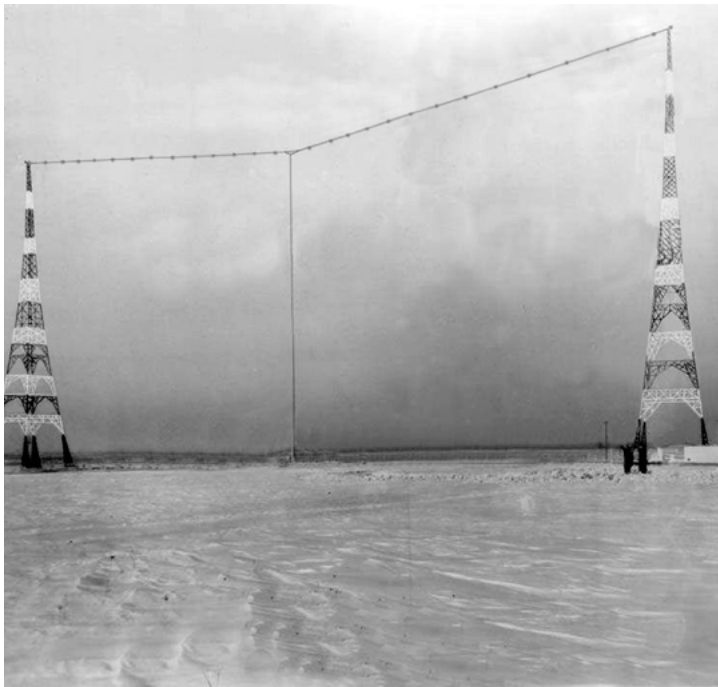
hurst, New Jersey.

More Directional Antennas

The proven success of these directional antennas convinced the FCC to accept the technology and create regulations for its use. This opened the floodgates for applications from dozens of other stations. In 1933, WJSV in Washington, DC, (now WFED) installed a directional antenna to reduce interference at the Naval Laboratories on the Potomac River while also increasing signal strength in Washington.

That same year, WKRC in Cincinnati installed a directional system to decrease interference to co-channel stations in Buffalo, New York, and St. Louis, Missouri. In 1934, WMC in Memphis was able to raise its power from 1 kW to 2.5 kW while protecting WTAR in Norfolk, Virginia. Its system consisted of an active vertical antenna and a passive 185-foot reflector mast spaced a quarter-wave distant on the bearing towards Norfolk.

A dozen other stations followed suit in 1935, including WINS in New York, KSD in St. Louis, Missouri, and KWKH in Shreveport, Louisiana. In 1936, WWJ, Detroit, Michigan, built a two-tower 5 kW directional system, and WBZ in Boston used two towers to reduce its signal over the Atlantic Ocean in 1939. In 1940, WEAJ New York (now WFAN) moved its transmitter site 8 miles closer to New York – from Bellmore Long Island. to Port Washington.



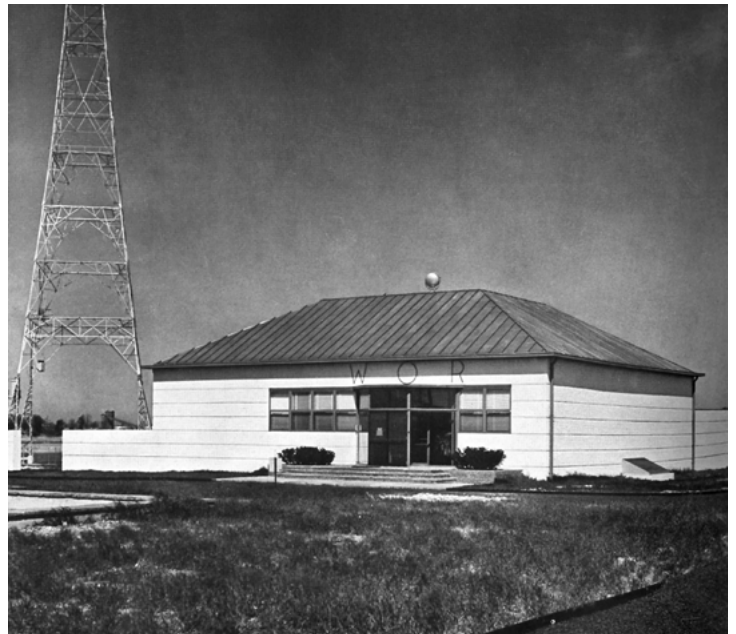
This 1935 photograph shows the WOR antenna system, with its two 385-foot towers and transmitter building. The drop-wire midway between the towers formed the third element of the directional array. (Author's collection)

Its two-tower system was designed to reduce the signal over the Atlantic Ocean and increase power towards the west.

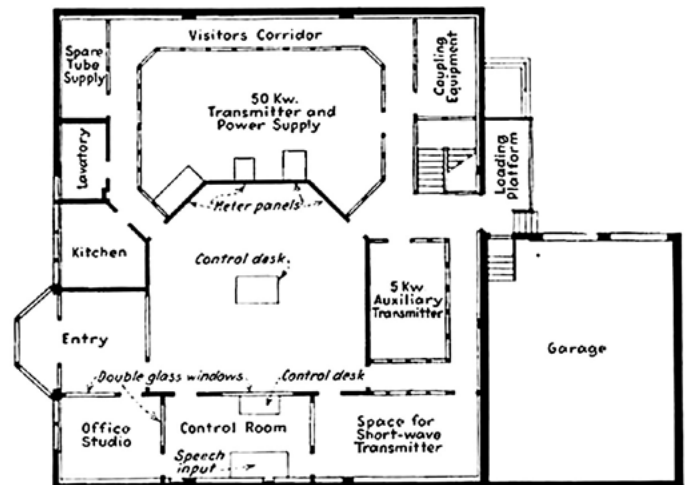
By 1940, directional AM antennas were enough of a proven technology that dozens of stations were using them to obtain power increases or fulltime operation. But in the years before computers, the current and phase parameters for each tower needed to be calculated by hand. This was mathematically complex and tedious process—understood by only a handful of expert radio engineers. The few who had early knowledge of these systems, such as T.A.M. Craven, were doing a brisk business designing new antenna systems. By the start of World War II, there were 646 AM radio stations on air in America, and 39 of them were using directional antennas.

In the early 1940s, Carl E. Smith (Cleveland Institute of Radio Electronics) built an elaborate electro-mechanical device that could calculate and draw antenna patterns. He published a 238-page book in 1936 that gave the parameters for over 15,000 possible two- and three-tower directional patterns. The publication of this reference work greatly simplified the design of directional arrays and made it easier for their design and construction.

When the wartime freeze on FCC applications was ended, hundreds of applications for new AM stations were submitted, with many specifying the use of directional antennas. Between 1940 and 1950, the number of AM stations in the USA tripled to 2,000, and then increased again to 4,000 by 1970. This was all made possible by the use of directional antenna technology. Today, the United States enjoys the greatest number of AM stations of any country in the world, and there are more directional antenna systems in the U.S. than all other countries combined.



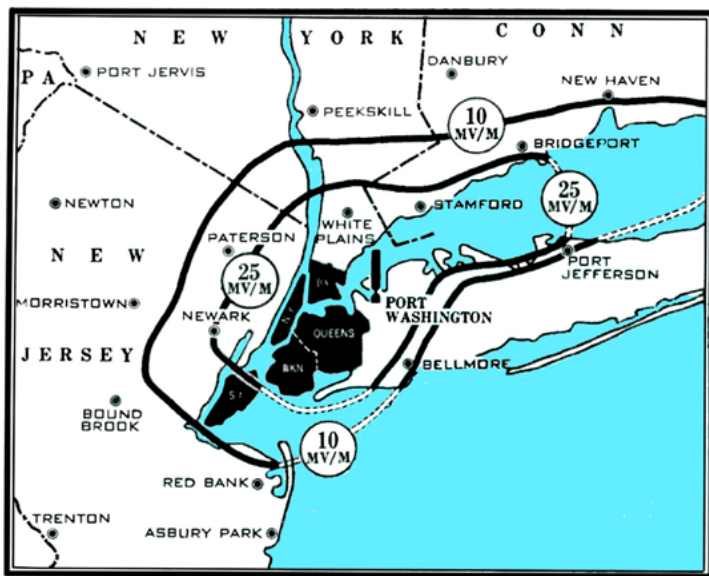
Here is a 1935 view of the WOR transmitter building. (Author's collection)



This is the floor plan of the WOR transmitter building. The corridors surrounding the transmitting equipment permitted visitors to view it during operating hours. (Electronics magazine, February 1935)



This is a rear view of the WEAF antenna system, showing the elevated raceway supporting the coaxial transmission line that connected the two towers. (Author's collection)



This coverage map shows the coverage that WEAJ achieved with its two-tower antenna system in Port Washington. Although most power was being radiated to the west, there was still considerable signal in Long Island Sound to the east because of its saltwater path. (Author's collection)

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This was the transmitter building and antenna system that NBC built for its key station WEAJ in Bellmore, Long Island, in 1940. NBC decided to use a two-tower directional system when its proposal for a single 740-foot tower was denied because of aircraft restrictions. (Author's collection)

July 1933

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